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Hasager, Charlotte Bay; Ahsbahs, Tobias Torben; Badger, Merete; Hansen, Kurt Schaldemose; Volker, Patrick

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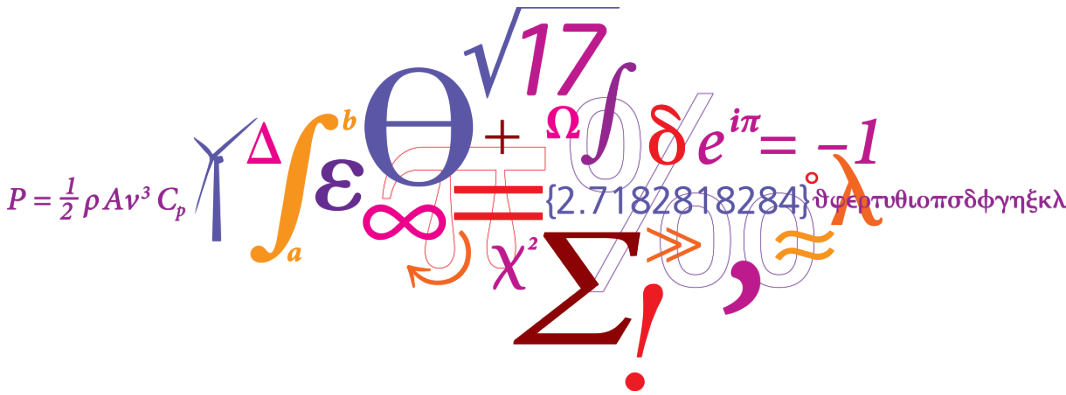
Comparisons of winds from satellite SAR, WRF and SCADA to characterize coastal gradients and wind farm wake effects at Anholt wind farm

Charlotte Hasager
Tobias Ahsbahs
Merete Badger
Kurt S. Hansen
Patrick Volker

News on satellite SAR



Vindkraftnet meeting, Ørsted, 9 April 2018

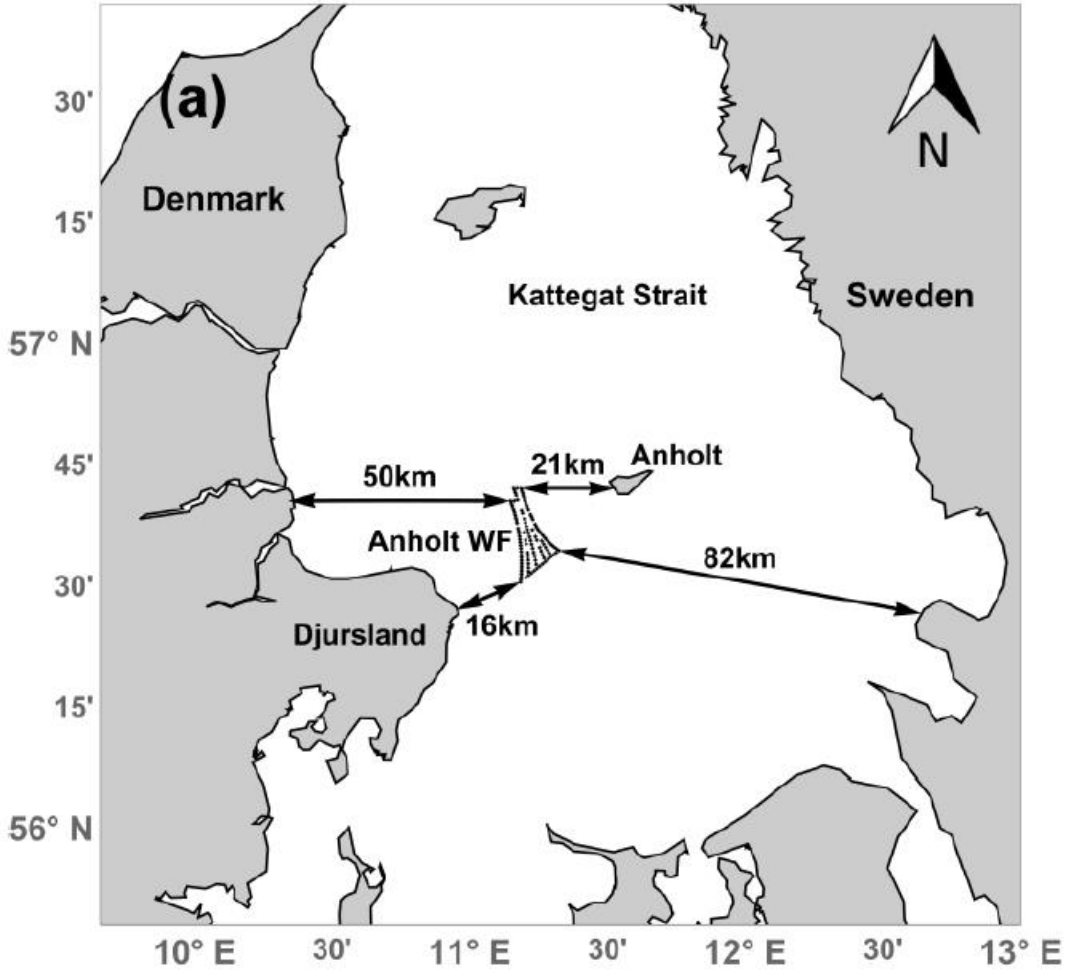
DTU Wind Energy
Department of Wind Energy

Content

- Anholt wind farm
- Wind speed data
- Coastal wind speed gradient
- Wind farm wake

- Satellite SAR news

Anholt wind farm in Kattegat



Anholt wind farm 2013

Wind speed data

SCADA:	01.2013 – 06.2015	(2.5 years, 10 minute)
Envisat ASAR:	08.2002 – 04.2012	(10 years)
Sentinel-1:	12.2014 – 05.2017	(3 years)
WRF:	01.2002 – 12.2017	(16 years, hourly)

SCADA

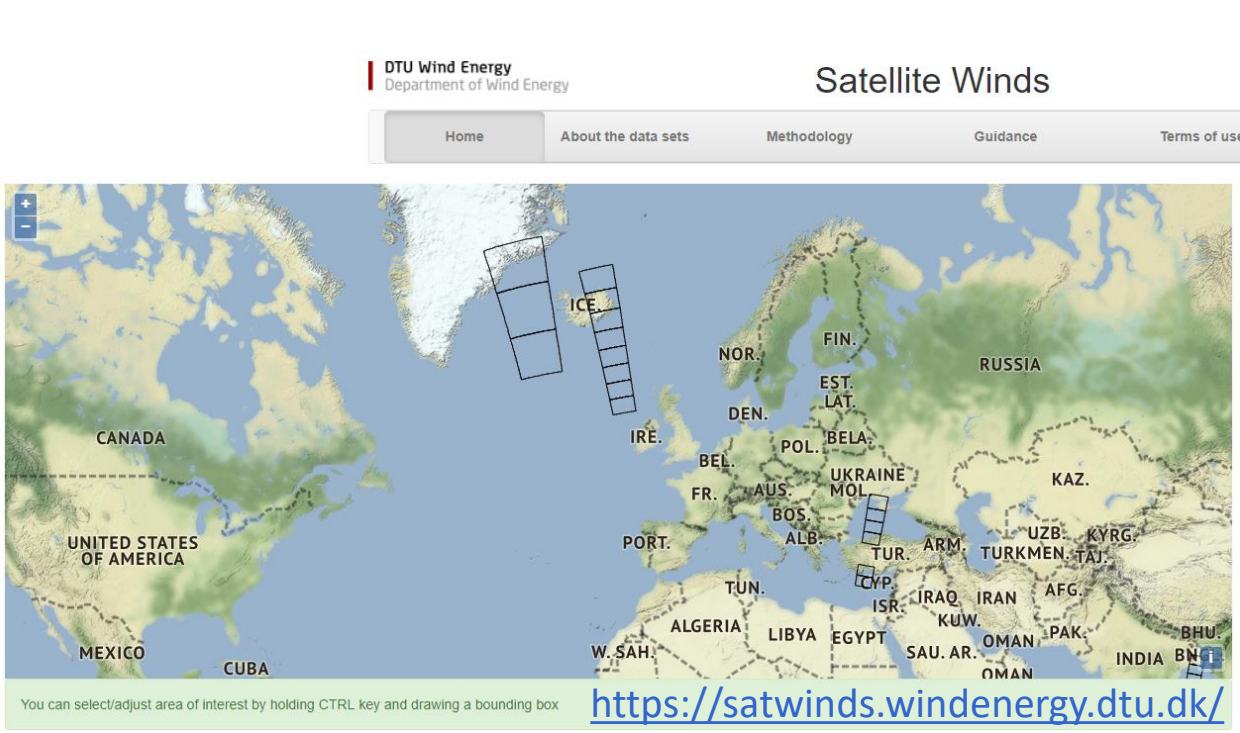
Exclude SCADA data when wind turbines are not grid connected or are not producing power during a complete 10-minute period or is curtailed.

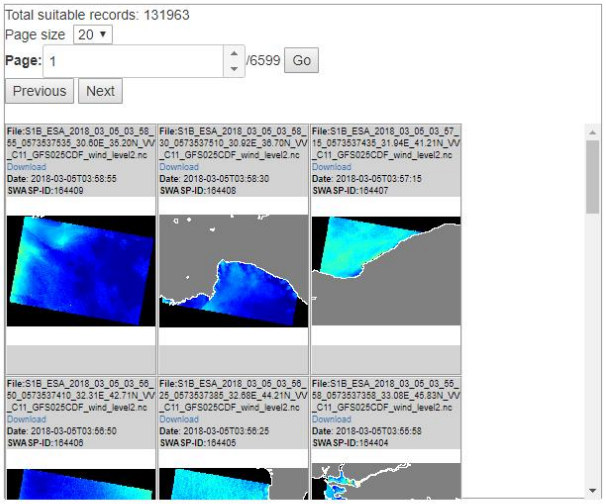
The remaining periods are applicable for analysis after a final examination of the power curve.

Peña, A. et al., 2017. On wake modeling, wind-farm gradients and AEP predictions at the Anholt wind farm. *Wind Energy, Science Discussions*, 2017, pp.1–18.

Satellite SAR wind data archive at DTU

- 30,000+ ENVISAT ASAR scenes (2002-2012)
- 100,000+ Sentinel-1 A/B SAR scenes (2014->)



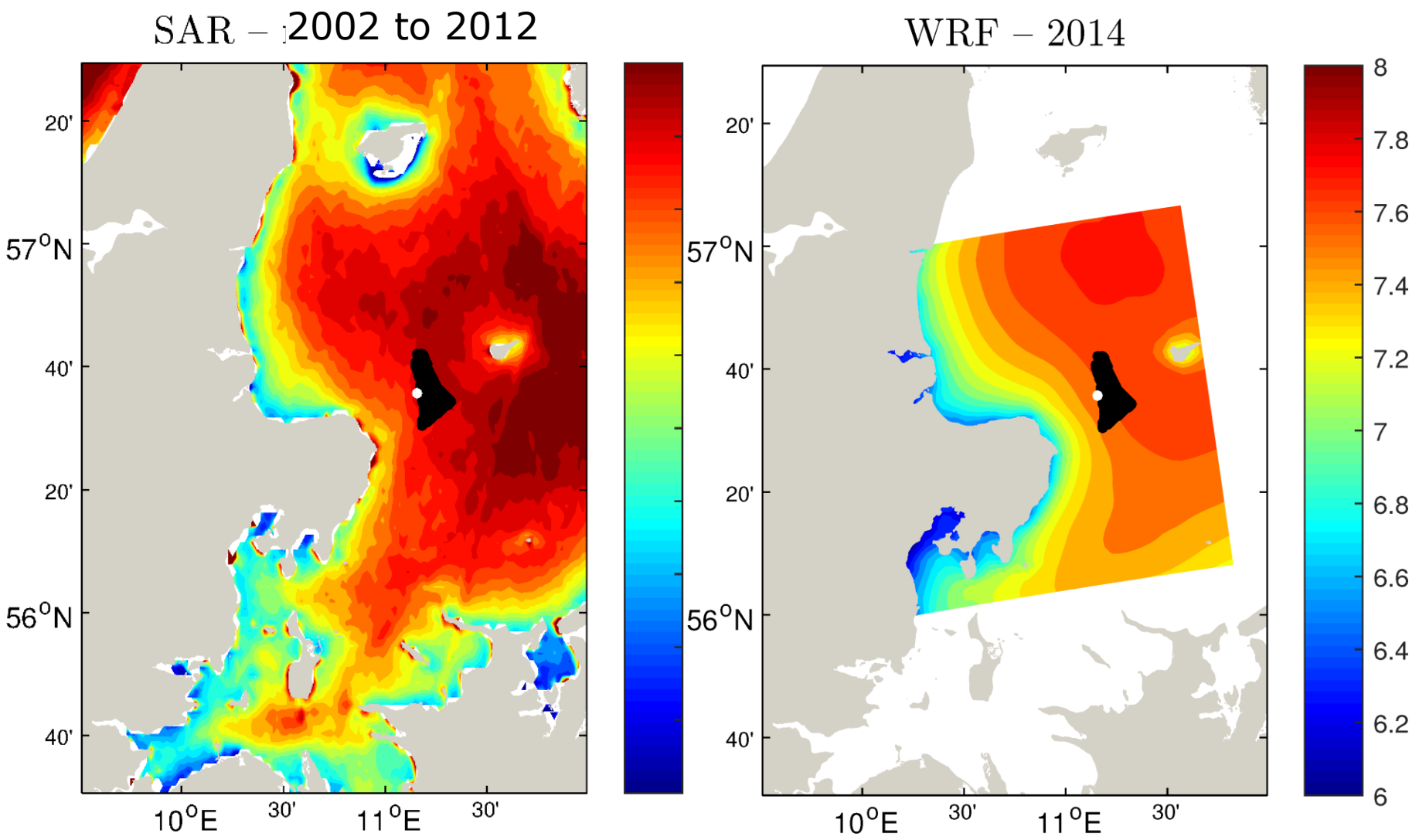


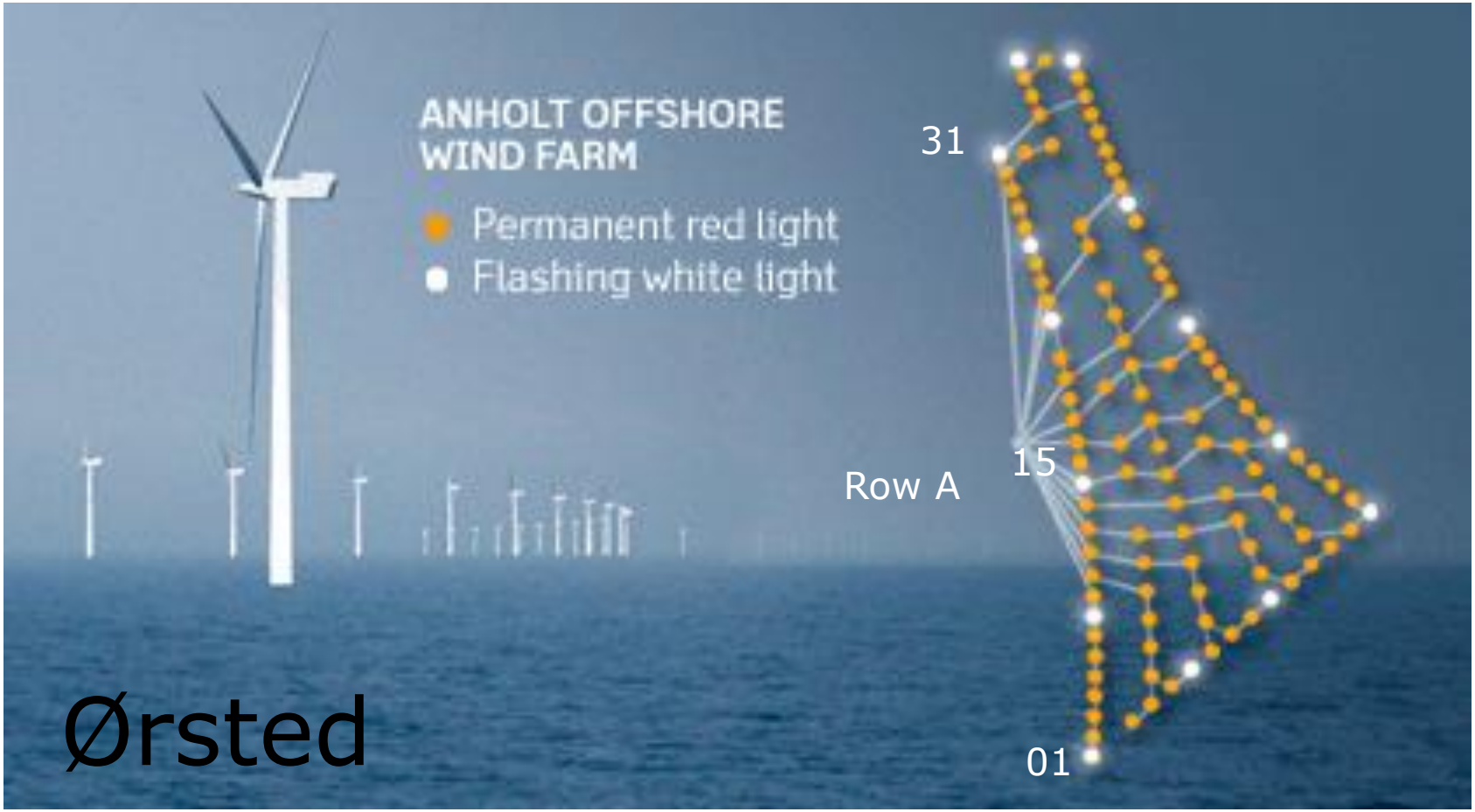
WRF

- The total simulated period covers 28 years from 1990 to 2017.
- The computational domain consists of three nests with an 18 km, 6 km and 2 km grid spacing.
- The outermost domain is forced by ERA-Interim Reanalysis. Using Yonsei University Scheme Planetary Boundary Layer scheme.

Further details in Peña, A. & Hahmann, A.N., 2017. *30-year mesoscale model simulations for the "Noise from wind turbines and risk of cardiovascular disease" project*, DTU Wind Energy E, Vol. 0055.

SAR and WRF mean wind speed at 10 m



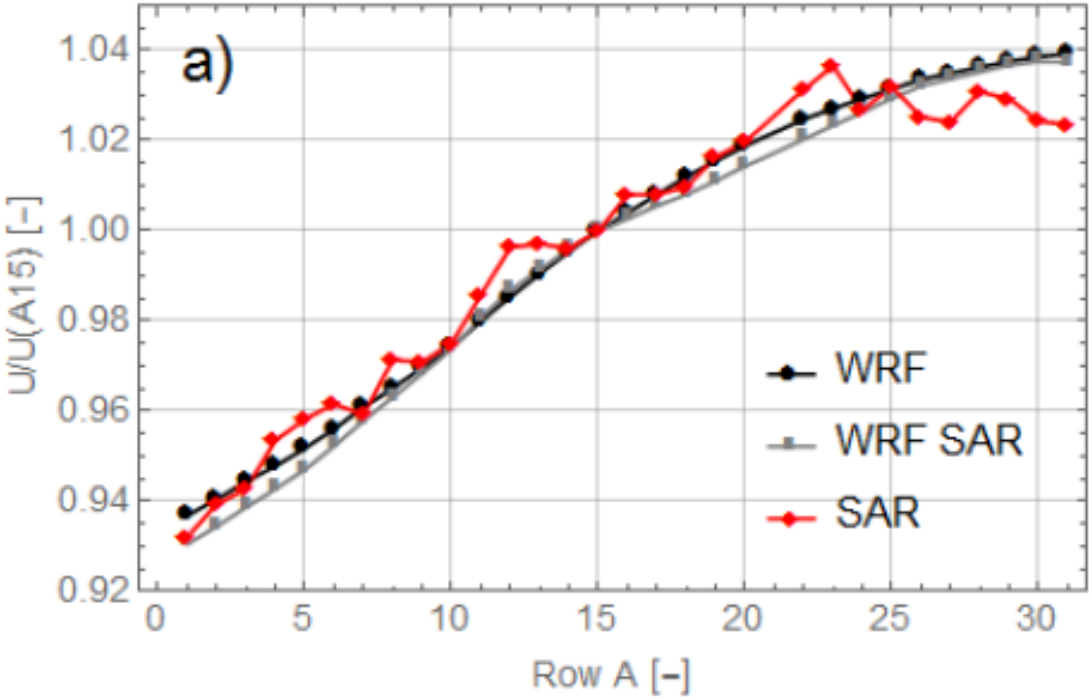

ANHOLT OFFSHORE
WIND FARM
Permanent red light
Flashing white light
31
15
Row A
01
Ørsted

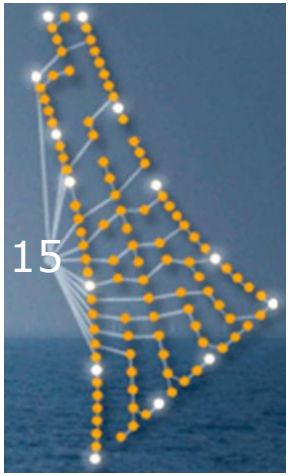
Wind conditions

Criteria

- Wind direction between 245° and 275°
- Above cut-in wind speed
- Data available for all turbines at Row A

SAR vs. WRF

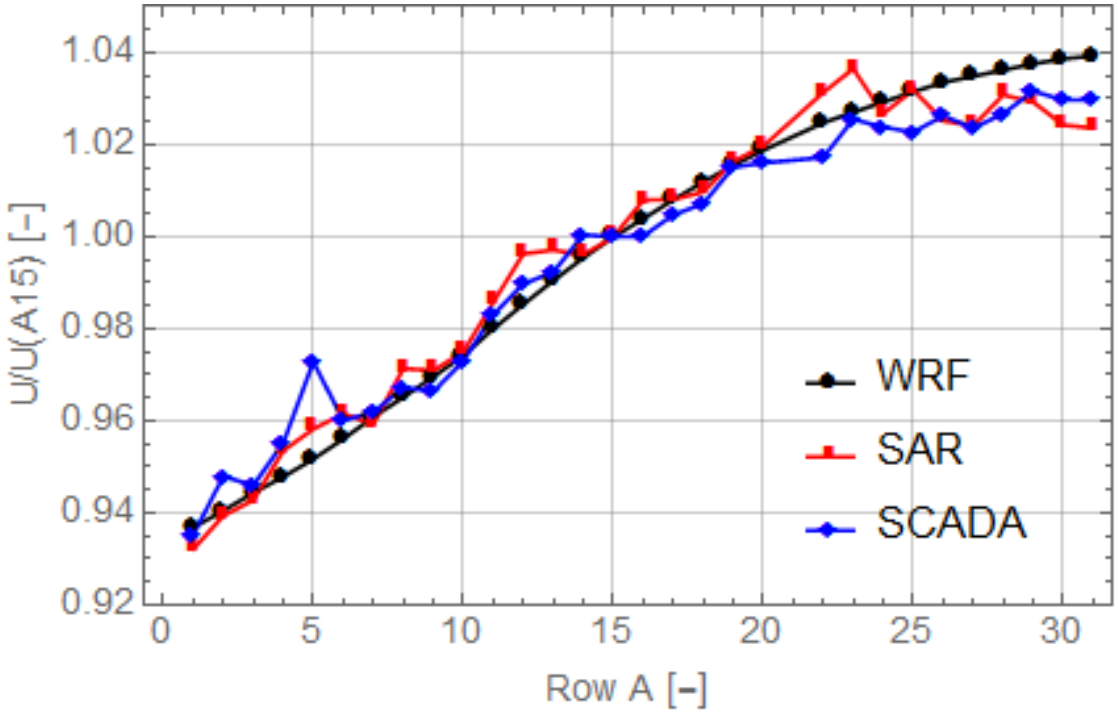


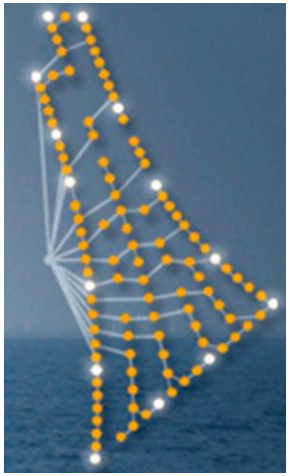


WRF (2002 to 2012) and WRF collocated with SAR.

The maximum deviation of mean wind speeds from the two WRF data sets is below 0.5%.

SAR vs. WRF vs. SCADA



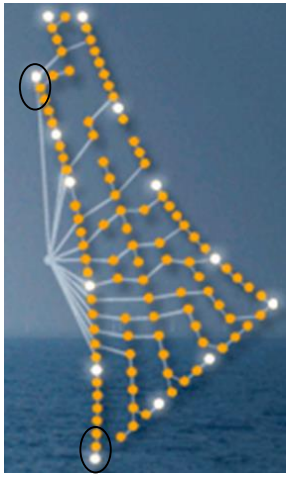


WRF (2002 to 2012), SAR (2002-2012) and SCADA (2013-2015).

Wind speed variation between North and South turbines at Row A

Table 3: Sample size and difference between most Northern and Southern turbines $\Delta U_{N,S}$ (three turbine location averaged).

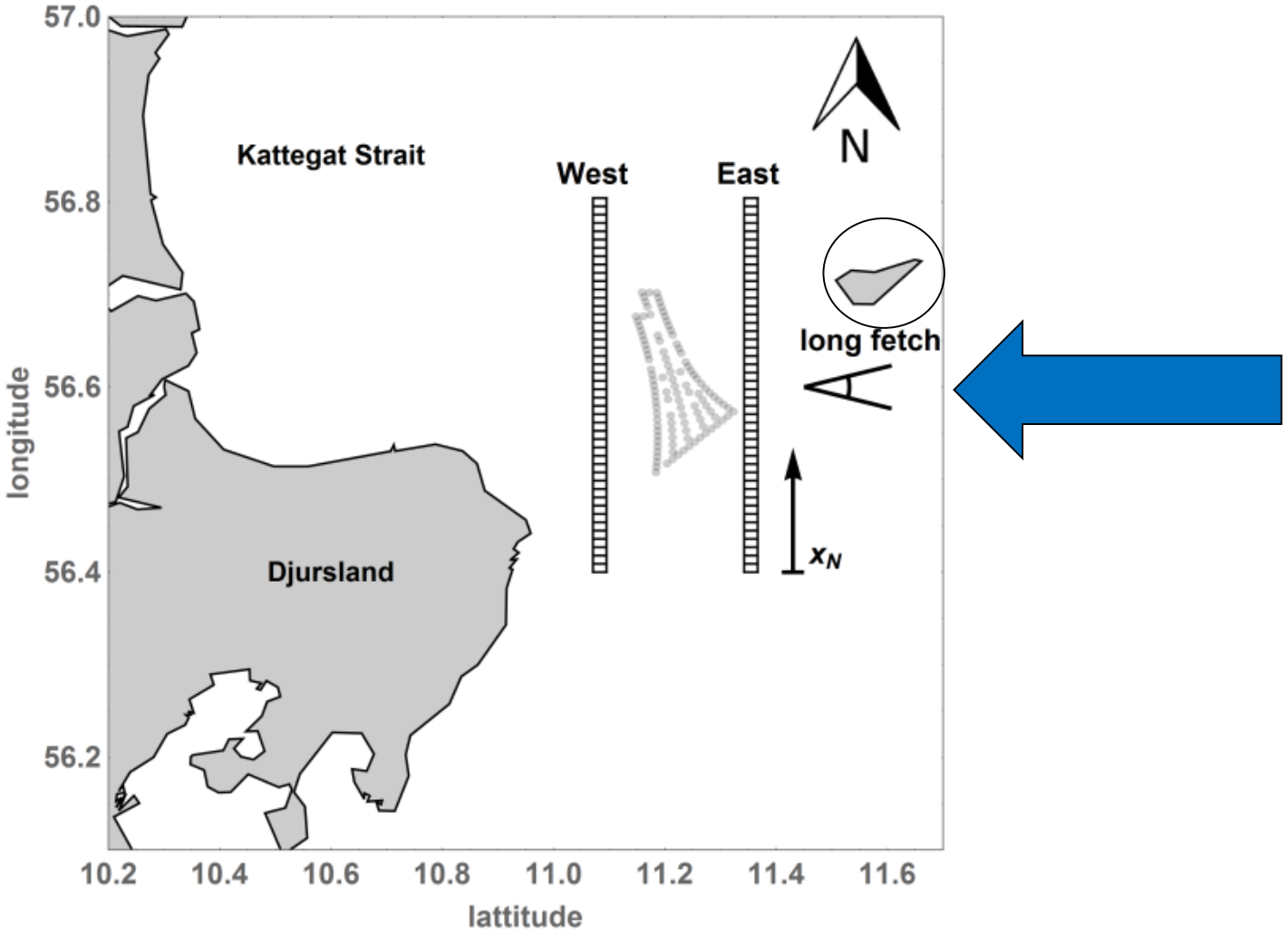
	SAR	WRF SAR	WRF	SCADA
Samples N [-]	72	72	10524	4625
$\Delta U_{N,S}$ [m/s]	0.92	1.02	0.98	0.95
$\Delta U_{N,S}/U_{15}$[%]	8.8	10.3	9.8	8.7



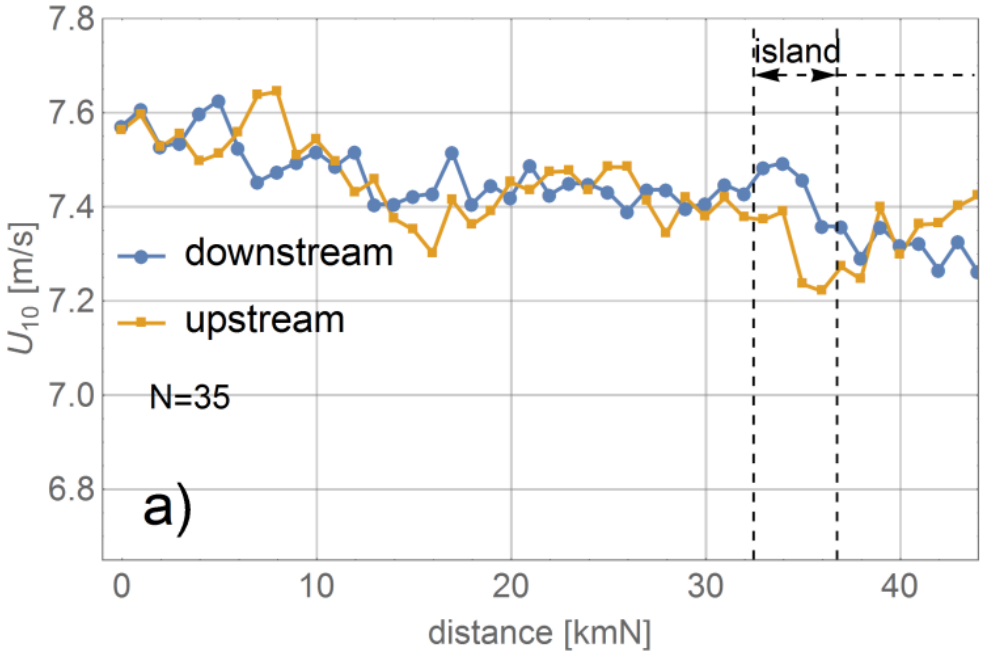
$$\Delta U_{N,S} = \sum_{i=A28}^{A31} U_i - \sum_{i=A01}^{A03} U_i$$

Wind farm wake analysis using SAR only

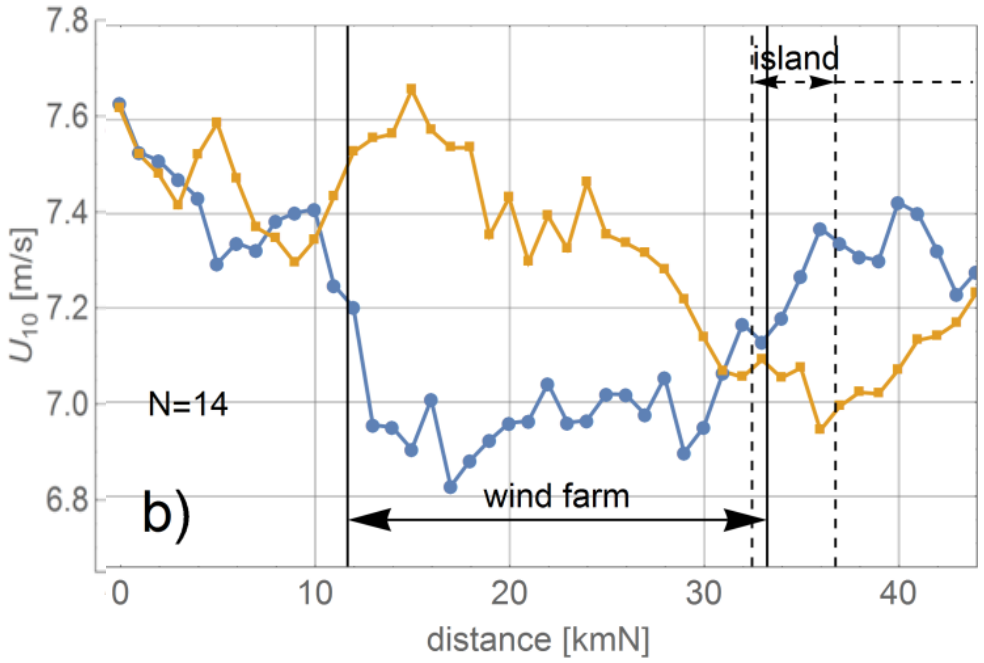
Two horizontal transects (East and West)



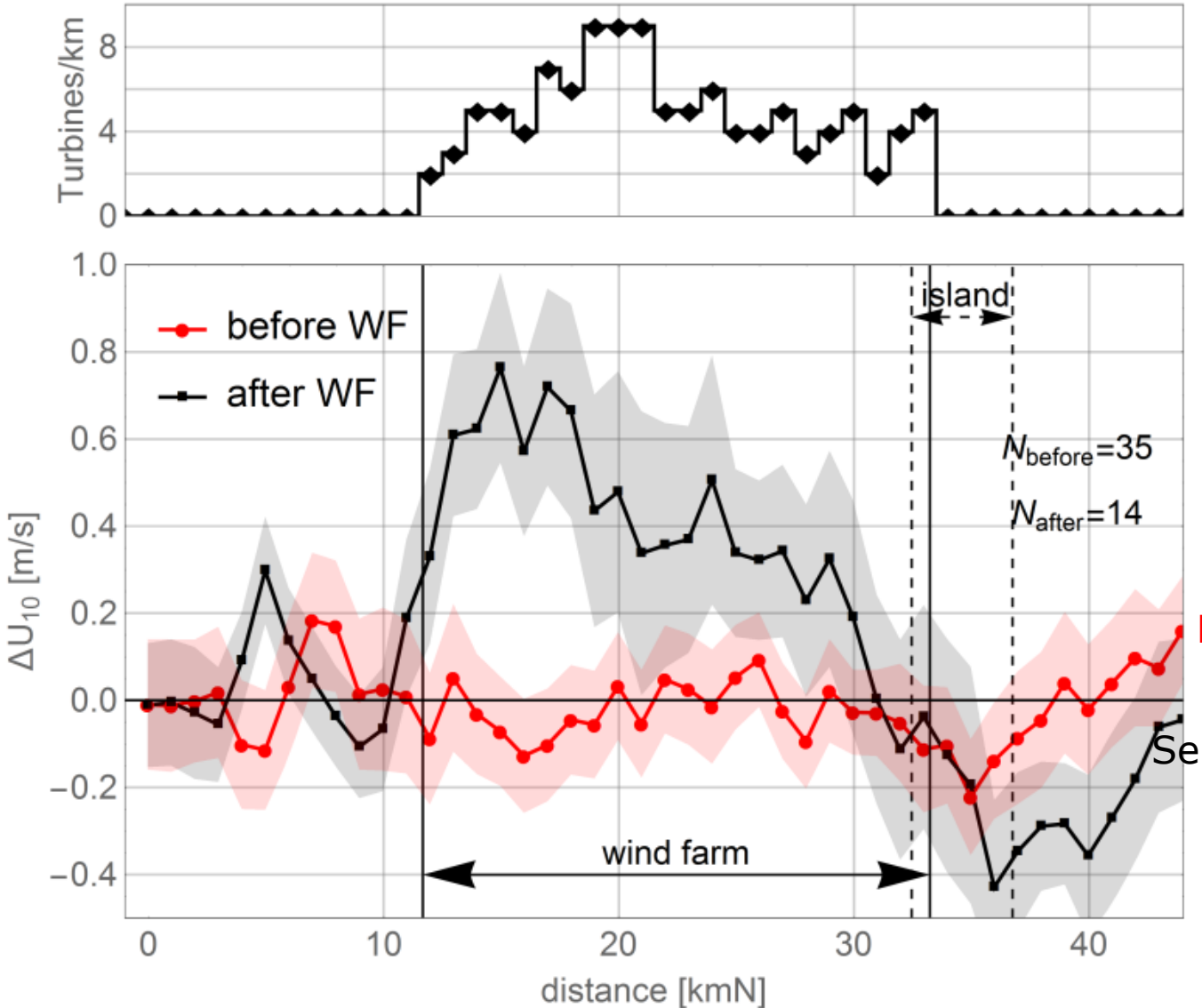
Before wind farm construction



After wind farm construction



Difference (East – West) and ± one std.dev.



Envisat 2002-2012

Sentinel-1 2014-2017

Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2018-2
Manuscript under review for journal Wind Energ. Sci.
Discussion started: 1 February 2018
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Applications of satellite winds for the offshore wind farm site Anholt

Tobias Ahsbahs[1], Merete Badger[1], Patrick Volker[1], Kurt S. Hansen[1], Charlotte B. Hasager[1]

[1]Department of Wind Energy, Technical University of Denmark, Roskilde, 4000, Denmark

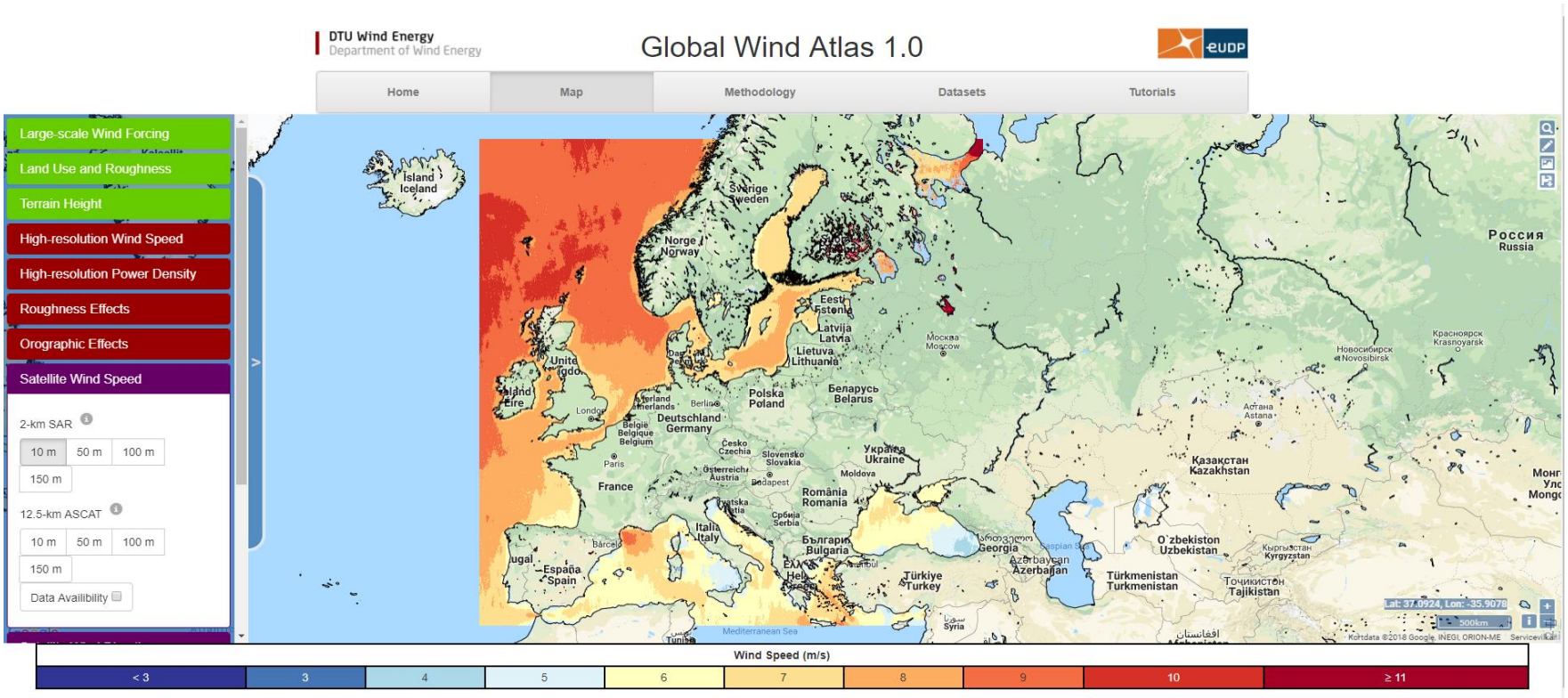
Correspondence to: Tobias Ahsbahs (ttah@dtu.com)

https://www.wind-energ-sci-discuss.net/wes-2018-2/

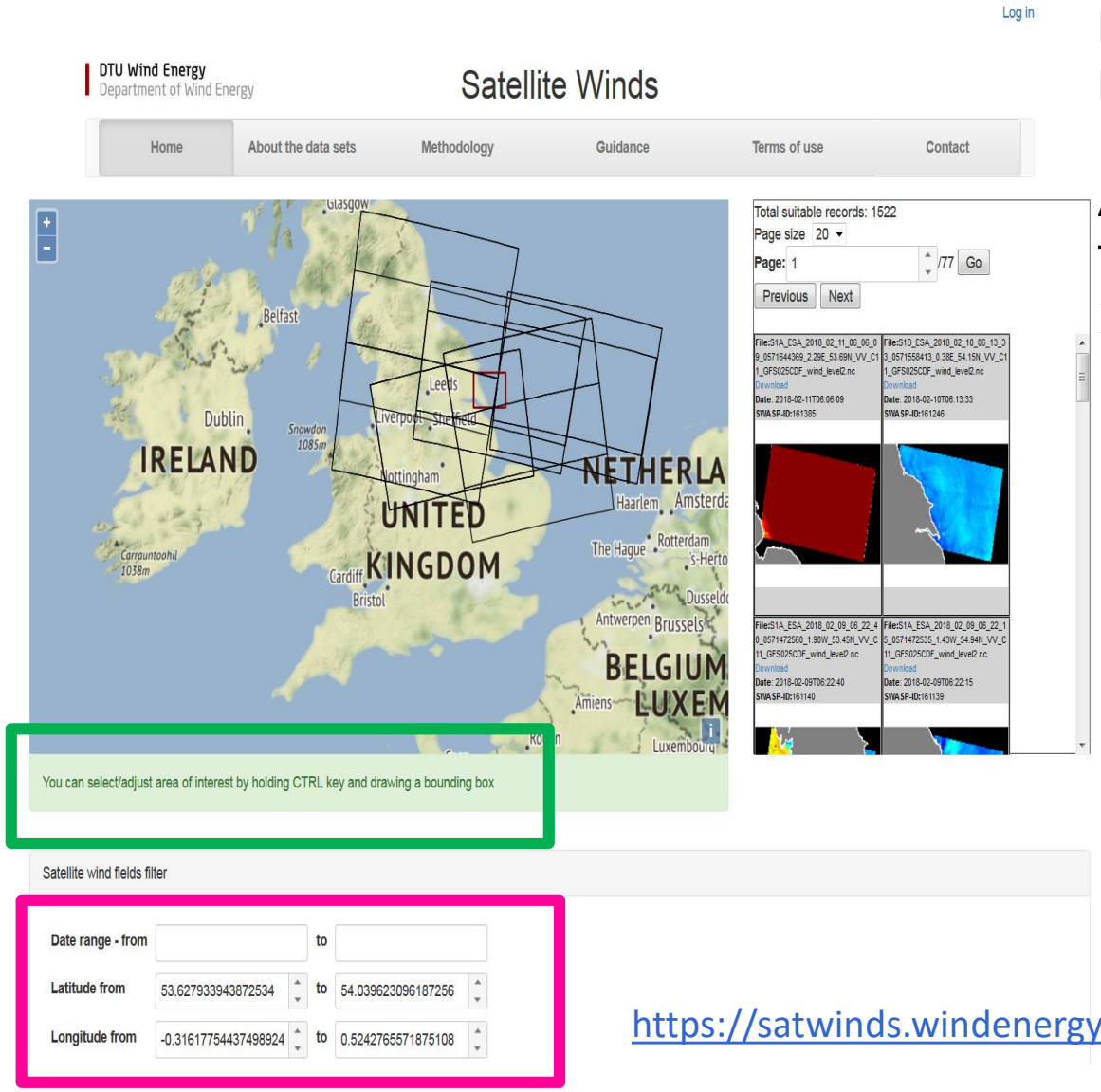
Satellite SAR wind news

Global wind atlas

http://science.globalwindatlas.info/science.html



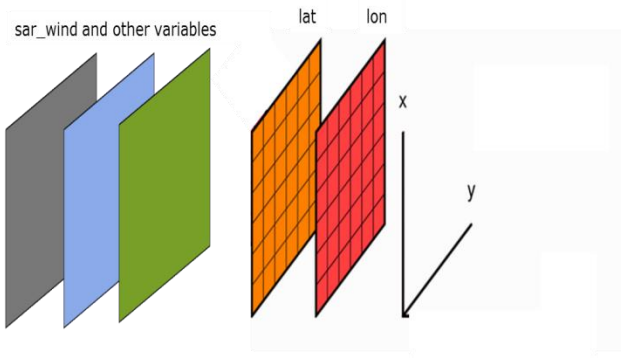
DTU Wind Energy satellite data station



Processed wind maps:
Define Area Of Interest (AOI)

AOI: Westermost Rough
Time period: Entire archive

➢ 1522 images



Format of single netCDF file

https://satwinds.windenergy.dtu.dk/

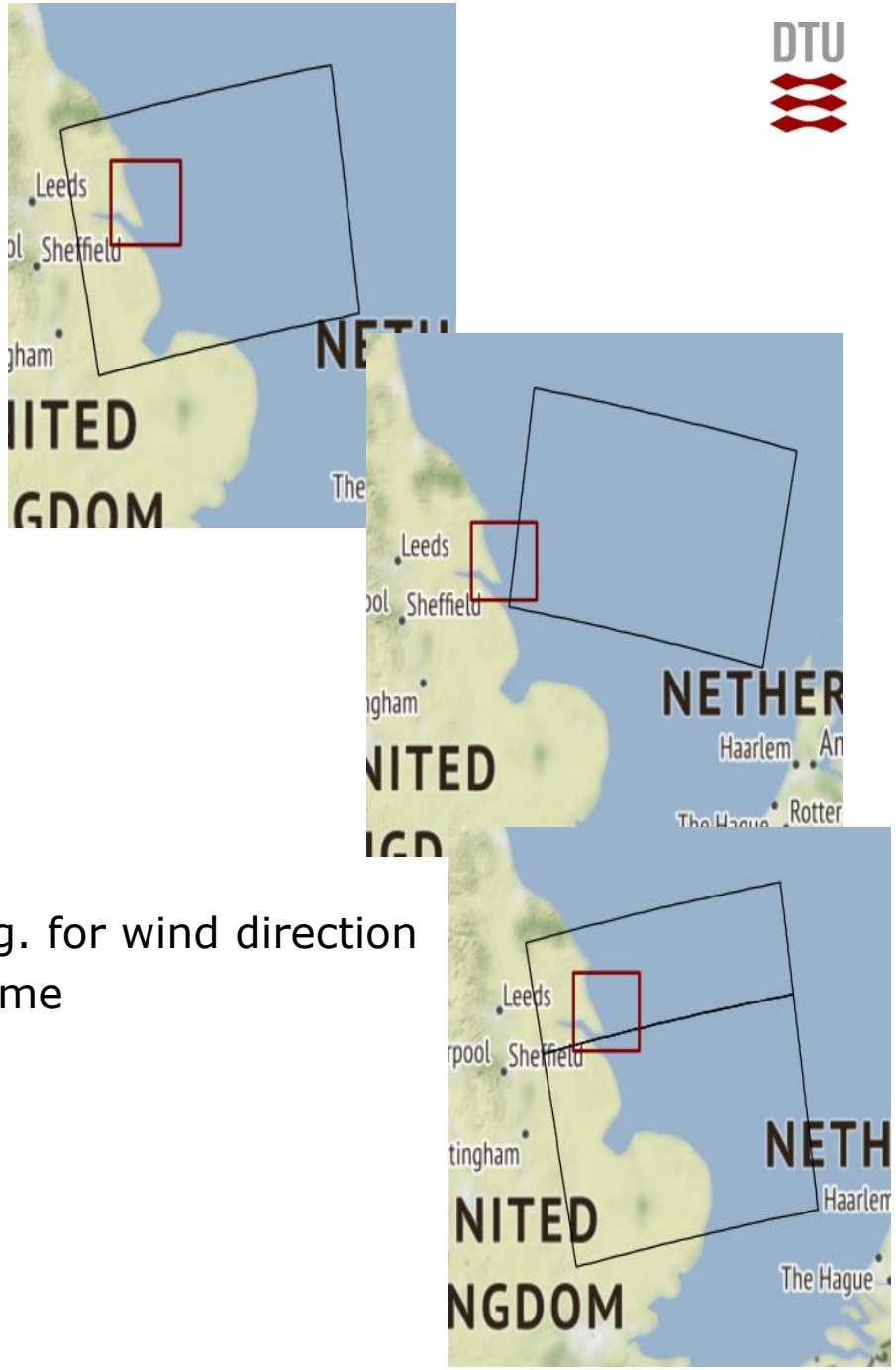
Ease of use

Westermost Rough example:

- More than 1500 single images
  - 1500 coordinate systems
  - 62GB of data

- Different image coverage
  - Full coverage
  - Partial coverage
  - Subsequent images

- Quantitative studies: Filtering data e.g. for wind direction
  - Data format makes this cumbersome



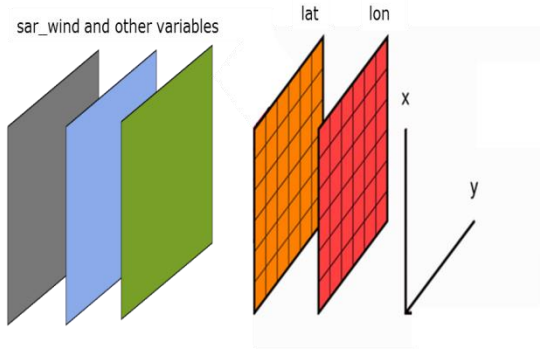
Solution

- Single netCDF with “time series” of SAR wind fields

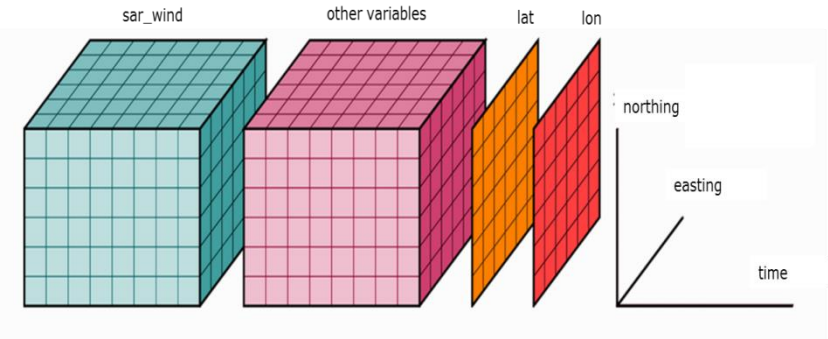
- Select AOI on the order of 25 km by 25 km
- Make a UTM coordinates (meters)
  - Nearest neighbour (accept up to 250m shift)
  - Only full coverage of AOI => constant sampling
  - Keep all information
- Implementation in python using xarray
- Output: netCDF file format

For the example:

- 1500 file to 1 file
- 1500 irregular grids to 1 UTM grid
- 62GB to 500MB (15min calculation)

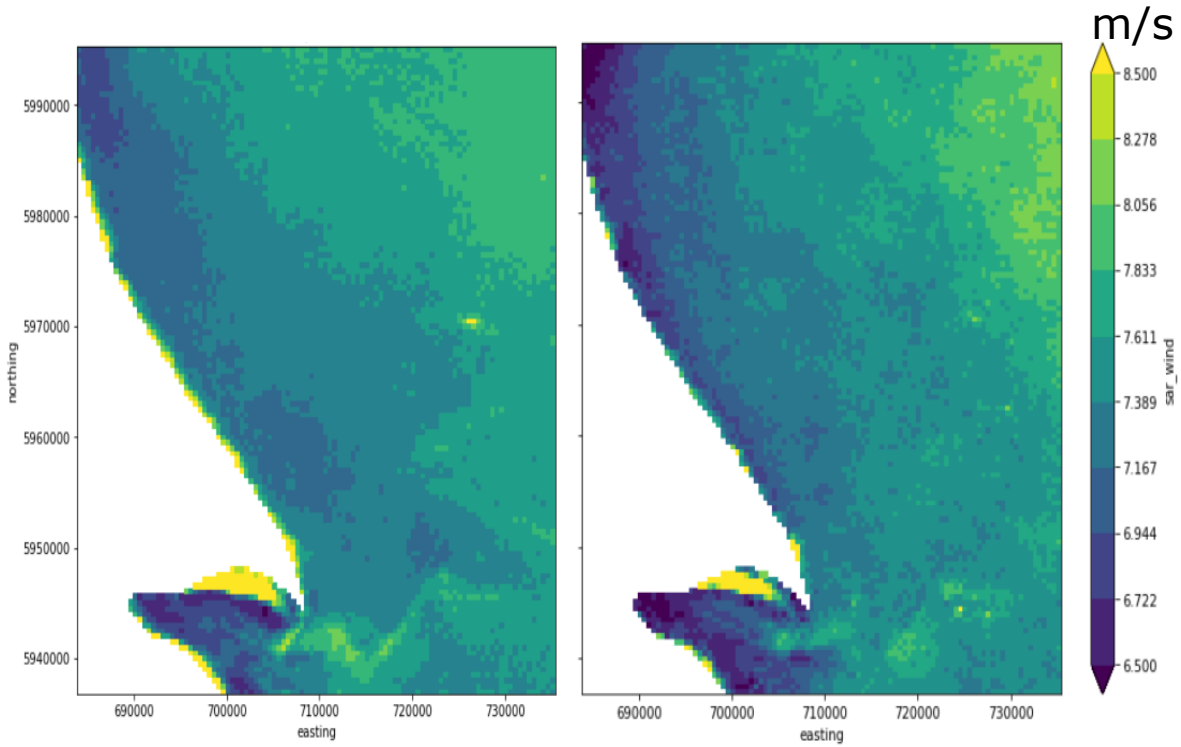


1500 single netCDF file



1 single netCDF file

Mean wind maps and coastal gradient study



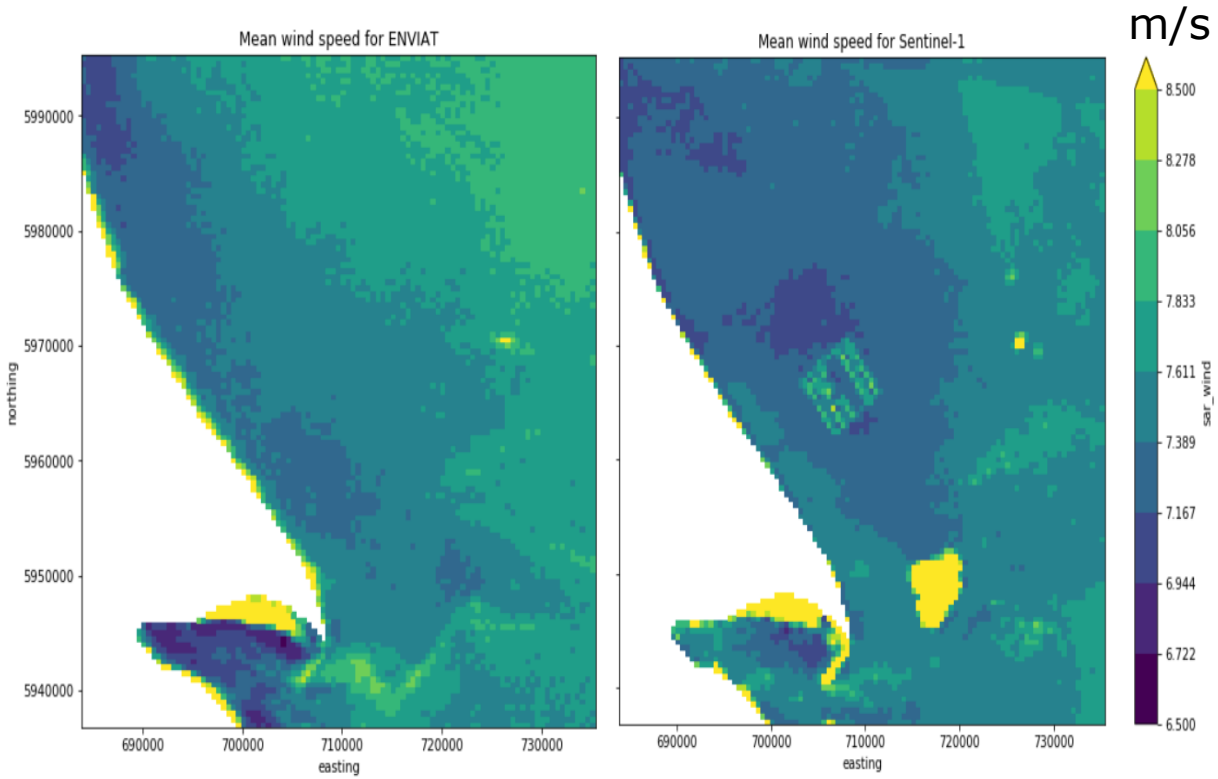
- Consistent sampling is important for wind speed gradients
- No borders between images

Mean wind speed from Envisat

Left: All wind directions (445 images)

Right: Images with wind directions between 240 and 300 degrees (77 images)

Wind speeds before and after wind farm construction



Left: All wind maps before the wind farm showing mean wind speed (Envisat ASAR)

Right: All wind maps after the wind farm showing mean wind speed (Sentinel-1)

What is this good for?

Fast and easy in:

- Local reprocessing
- Filtering and selecting
- Debugging of analysis

Easily integrate other data sources:

- Can be used for validation and verification on offshore wind speeds

Acknowledgements

We would like to acknowledge:

- Ørsted and partners for granting access to data from the Anholt wind farm,
- Johns Hopkins University Applied Physics Laboratory and the National Atmospheric and Oceanographic Administration (NOAA) for the use of the SAROPS system,
- ESA for providing public access to data from Envisat ASAR,
- Copernicus for providing public access to data from Sentinel-1.